



U.S. Department  
of Transportation

**Federal Aviation  
Administration**

# Memorandum

Subject: INFORMATION: Review and Concurrence, Equivalent Level of Safety (ELOS) finding for Flight Critical Thrust Reversers on Raytheon Aircraft Company's Model 4000

Date: April 17, 2003

From: Manager, Propulsion/Mechanical Systems, ANM-112  
Transport Airplane Directorate

Reg. Ref. § 25.933(a)(1)(i) and (ii)

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ELOS TC1258WI-T-P-1  
Memo#

The purpose of this memorandum is to document the Equivalent Level of Safety (ELOS) addressed herein in a manner that is nonproprietary and that can be made available to the public. To facilitate archiving and retrieval of this ELOS finding, a unique ELOS number (TC1258WI-T-P-1) has been assigned to this memorandum. This number should be listed in the Type Certificate Data Sheet under the Certification Basis, ELOS section.

**Background:** Raytheon Aircraft Company has stated that the Model 4000 will not meet the applicable airworthiness requirement [§25.933(a)(1)(i) and (ii)], which state "Each operable reverser can be restored to the forward thrust position" and "The airplane is capable of continued safe flight and landing under any possible position of the thrust reverser" respectively. Therefore, in accordance with the provisions of §21.21(b)(1) the airworthiness provision not complied with must be compensated for by factors that provide an equivalent level of safety.

Raytheon Aircraft Company (RAC) intends to demonstrate that the nature and reliability of the Model 4000 Thrust Reverser design is such that it protects against in-flight reverser deployment to an extent that provides a level of safety equivalent to that provided by direct compliance with §§ 25.933(a)(1)(i) and (ii). RAC plans to use an approach consistent with the Equivalent Safety Finding Generic Issue Paper for Flight Critical Thrust Reversers issued through the Transport Airplane Directorate.

**Applicable regulations:** §§ 21.21(b)(1), 25.933(a)(1)(i) and (ii), 25.1309(b)(1)

**Regulations not complied with:** §25.933(a)(1)(i) and (ii)

**Guidance with respect to addressing the compensating features which allow the granting of the ELOS (including design changes, limitations or equipment need for equivalency):**

Compliance with §25.933(a)(1)(ii) is intended to completely eliminate all risk of catastrophic in-flight reverser deployment from normal operation. Under §25.933(a)(1)(ii), any residual risk of catastrophic in-flight reverser deployment would be limited to scenarios involving unusual aircraft configurations, abnormal flight conditions or inappropriate flight crew actions. Therefore, any design intended to provide an equivalent level of safety to the subject rule must limit the residual risk of catastrophic in-flight reverser deployment to a similar level.

In general, the catastrophic risks from other aircraft system hazards are identified and managed through compliance with §25.1309(b)(1). Therefore compliance with this standard by the means delineated in the related AC25.1309-1A should be part of any equivalent safety finding utilizing probability that a catastrophic in-flight deployment is not expected to occur. However, as documented in the docket justification for the subject §25.933 rule, "A review of the past operating history of airplane engine thrust reversers indicates that fail-safe design features in the reverser systems do not always prevent unwanted deployment in flight. Many of these unwanted deployments are not caused by deficiencies in design but can be attributed to maintenance omissions, wear and other factors that cannot be completely accounted for in the original design and over which the manufacturer generally has no control even when comprehensive maintenance programs are established." This perspective has been re-enforced by a 1992 AIA/FAA review of transport service history, which indicates that many of the reverser in-flight deployment incidents involved inadequate maintenance or improper operations. Other factors such as uncontained engine failure, unanticipated system failure modes and effects, and inadequate manufacturing quality have also played a role in in-service deployment incidents.

Therefore, in addition to the traditional reliability predictions provided in demonstrating compliance with §25.1309, any equivalent safety finding to §25.933 will require that the influences which could render that prediction invalid be identified and acceptable means for managing these influences be defined. To this end, compensating design assurance and continued airworthiness features must be provided for FAA Aircraft Certification approval which, as a minimum, address:

- 1) justification for any assumptions made in the System Safety Analysis (SSA) including:
  - (a) rationale for failure modes considered;
  - (b) failure effects determination and verification methods;
  - (c) criteria for assuring the completeness of any top down analysis (*e.g. dependency diagrams, fault tree analysis (FTA), etc.*);
  - (d) rationale for failure rate data source applicability including consideration of relative design and manufacturing standards as well as the installation environment;
  - (e) methods by which failures will be detected, isolated and eliminated consistent with the assumed exposure times (*e.g. exposure time may be justified by providing reference tracability to an FMEA that provides the resultant detection means, the MMEL or MRB documents that set the detection interval, and the Trouble Shooting and/or Maintenance Procedures that set the effective interval required to isolate and eliminate the fault*); and
  - (f) verification of any fault independence assumptions (*e.g. independence between all failure conditions contributing to any FTA "and gate"*).

When providing these justifications, the effects of other systems which have physical, zonal or functional interfaces with the reverser must be taken into account. *(i.e. failures within the airplane hydraulic, ECS or electrical systems may be significant to the SSA. Also engine uncontained failure or fire may have a significant impact on the integrity of the thrust reverser and must be addressed.)*

2) all applicable lessons learned from the collective fleet experience delineated in Appendix A of the "Criteria for Assessing Transport Turbojet Fleet Thrust Reverser System Safety" including:

- (a) providing protection from inadvertent crew actuation;
- (b) validating the accuracy and effectiveness of flight deck design and crew procedures as they relate to reverser operation and failure modes;
- (c) limiting reliance on use of aerodynamic means to keep the reverser stowed;
- (d) minimizing of and justification for any latent failures (this should include latency due to faults which are "made latent" either due to loss of the detection means or due to the fault being intermittent);
- (e) providing system contamination tolerance;
- (f) validating maintainability, both in the design and procedures. This validation should include at least verification that the system and procedures support the SSA assumptions, are tolerant to anticipated human errors, and that any critical procedures are highlighted for consideration as required inspection items *(e.g. if under some anticipated dispatch conditions an improperly performed reverser lock-out procedure could leave the reverser without any active restraint, depending on the potential for mis-maintenance, this procedure may need to be independently witnessed by an approved inspector.)*
- (g) providing protection from common mode failure sources such as environmental conditions, engine uncontained failure, and fire.

3) means to monitor and report inservice experience relative to thrust reverser system safety and effectively respond to any conditions, which may invalidate this equivalent safety finding.

**Description of the demonstrations that can be considered compensating factors that will allow the granting of the ELOS (including design changes, limitations or equipment need for equivalency):**

Raytheon Aircraft Company has declared that the Model 4000 will not be shown to directly comply with §§25.933(a)(1)(i) and (ii). RAC has elected to demonstrate that the Model 4000 is protected against catastrophic in-flight reverser deployment to an extent that the demonstration provides a level of safety to that provided by direct compliance with the rule. The FAA will accept that an equivalent level of safety has been achieved when the following is demonstrated:

- 1) A rigorous qualitative safety analysis to show that no single failure or malfunction, regardless of the probability, can result in a catastrophic in-flight reverser deployment. In addition to the traditional Failure Modes and Effects Analysis (FMEA), a top down analysis, at least to the assembly level, should be performed to assure that any obscure single failure modes are identified.
- 2) An average risk analysis in accordance with AC25.1309-1A, which predicts that catastrophic in-flight reverser deployment is not expected to occur in the fleet life of the Model 4000;

- 3) A specific risk analysis which predicts that at the beginning of each flight of a particular aircraft, it will continue to meet the "no single failure" criteria of analysis #1 above and that the risk of catastrophic in-flight deployment is less than  $1 \times 10^{-6}$  / ft.hr. This analysis is only required if the design can have contributory faults present for more than one flight. This analysis must consider any aircraft configuration (including latent faults) anticipated to occur in the fleet life of the airplane type, which is not proposed to be precluded from dispatch by the MMEL. For the purpose of this analysis a configuration whose probability of occurrence is greater than  $1 \times 10^{-8}$  must be assumed to occur unless a lower total fleet exposure time can be justified by prescribing either production or utilization limits. This analysis provides a previously unavailable tool to assist in the assessment of MMEL and MRB proposals.
- 4) Verification that the influences, which could render these predictions invalid, have been identified and acceptable means for managing these influences throughout the fleet life of the Model 4000 have been defined and implemented.

Demonstration of the items listed above satisfy the criteria for an ELOS as outlines in the Equivalent Safety Finding Generic Issue Paper for Flight Critical Thrust Reversers issued through the Transport Airplane Directorate and reiterated in the Background section of this Memorandum. RAC has proposed a safety analysis methodology that in addition to the traditional reliability predictions provided in demonstrating compliance with §25.1309, identifies those influences which could render the predictions invalid and provides an acceptable means for managing those influences.

#### **FAA approval of the ELOS**

The FAA has reviewed Raytheon Aircraft Company's thrust reverser system and proposal for providing an ELOS to §25.933(a)(1)(i) and (ii) and concurs.

/s/

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Date: April 17, 2003